

Single trial EEG classification of tasks with dominance of mental and sensory attention with deep learning approach

Irina Knyazeva³⁴, Alexander Efitorov¹², Boytsova Yulia⁵,
Sergey Danko⁵, Vladimir Shiroky⁴, Nikolay Makarenko^{1,2}

¹ National Research Nuclear University MEPhI, Moscow;

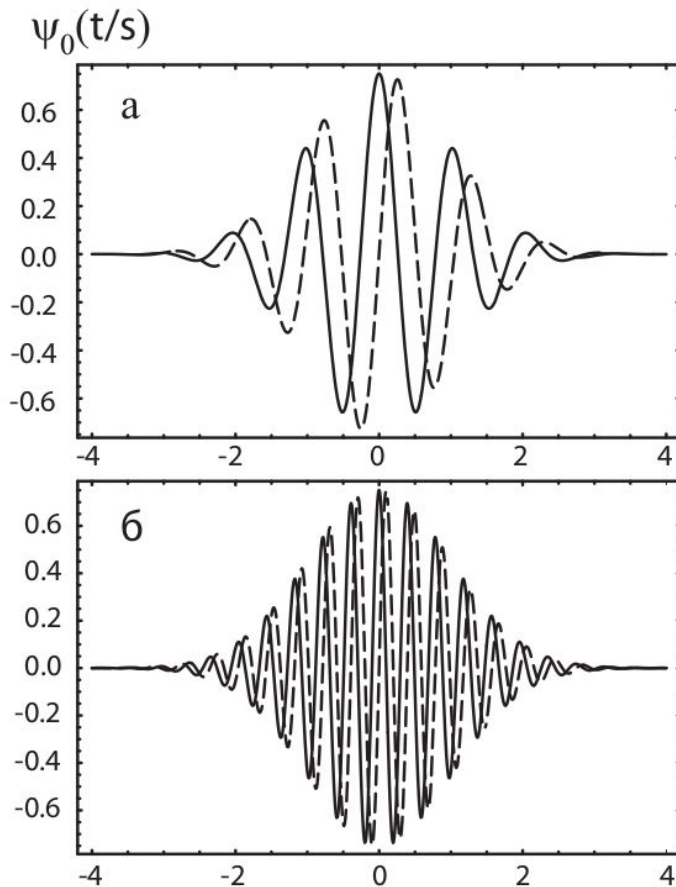
² Skobeltsyn institute of nuclear physics, Lomonosov Moscow State University, Moscow;

³ Pulkovo Observatory, St. Petersburg;

⁴ Saint-Petersburg State University, St. Petersburg;

⁵ Institute of the Human Brain, Russian Academy of Sciences, St. Petersburg;

Wavelet analysis

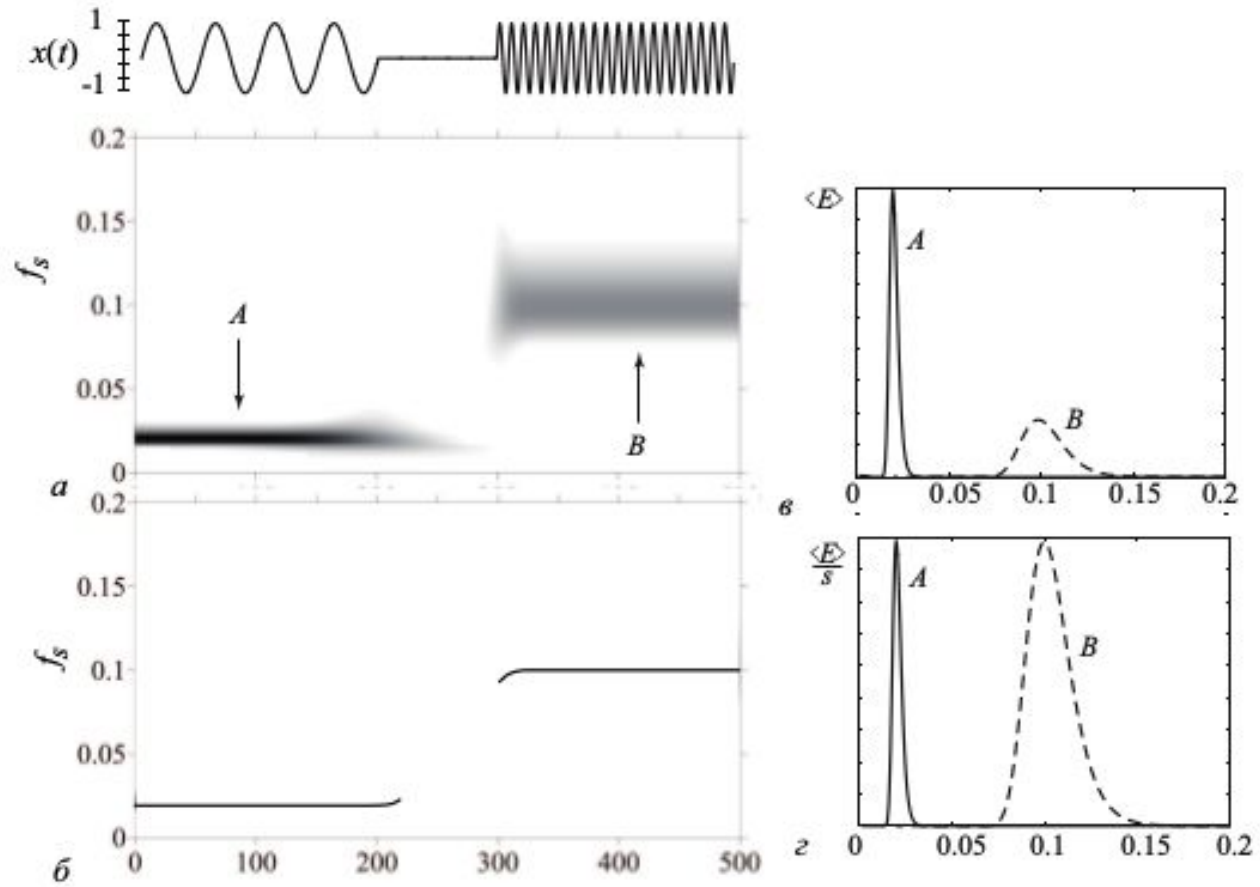


$$W(s, t_0) \simeq \int_{t_0 - T(s)}^{t_0 + T(s)} f(t) \psi_{s, t_0}^*(t) dt.$$

Wavelet Morlet:

$$\psi_0(\eta) = \pi^{-1/4} \left(e^{j\omega_0\eta} - e^{-\omega_0^2/2} \right) e^{-\eta^2/2},$$

Wavelet non-stationary nature



Experiment

- The study involved 28 healthy subjects (17 women and 11 men);
- Average age 29

Two types of task were investigated: **mental** attention (MA) and **sensory** attention (SA)

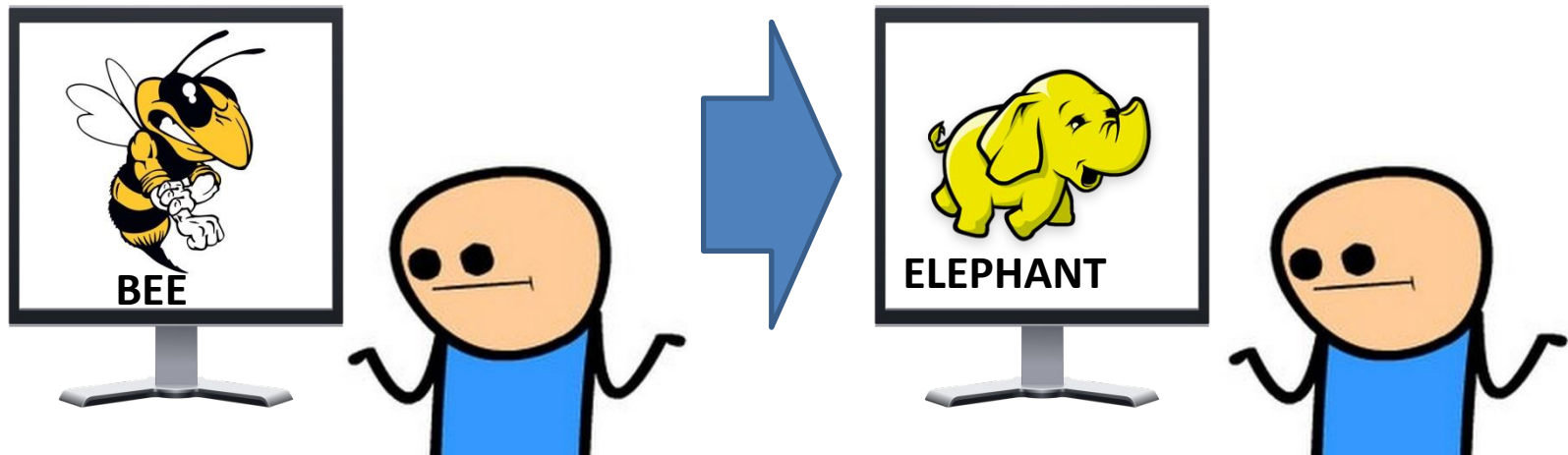
Experiment

- **Mental** attention: the subjects memorized images and corresponding nouns (for example: an apple, a bee, etc.). After that the subjects were consistently presented with words and asked to remember and visualize the appropriate image against the background of the computer's white screen.
- **Sensory** attention, the subject was consistently presented with two words (for example apple and bee) and, looking at the computer's white screen, asked to visualize a chimera image corresponding to two words simultaneously (for example: an apple with wings of a bee).

Experiment

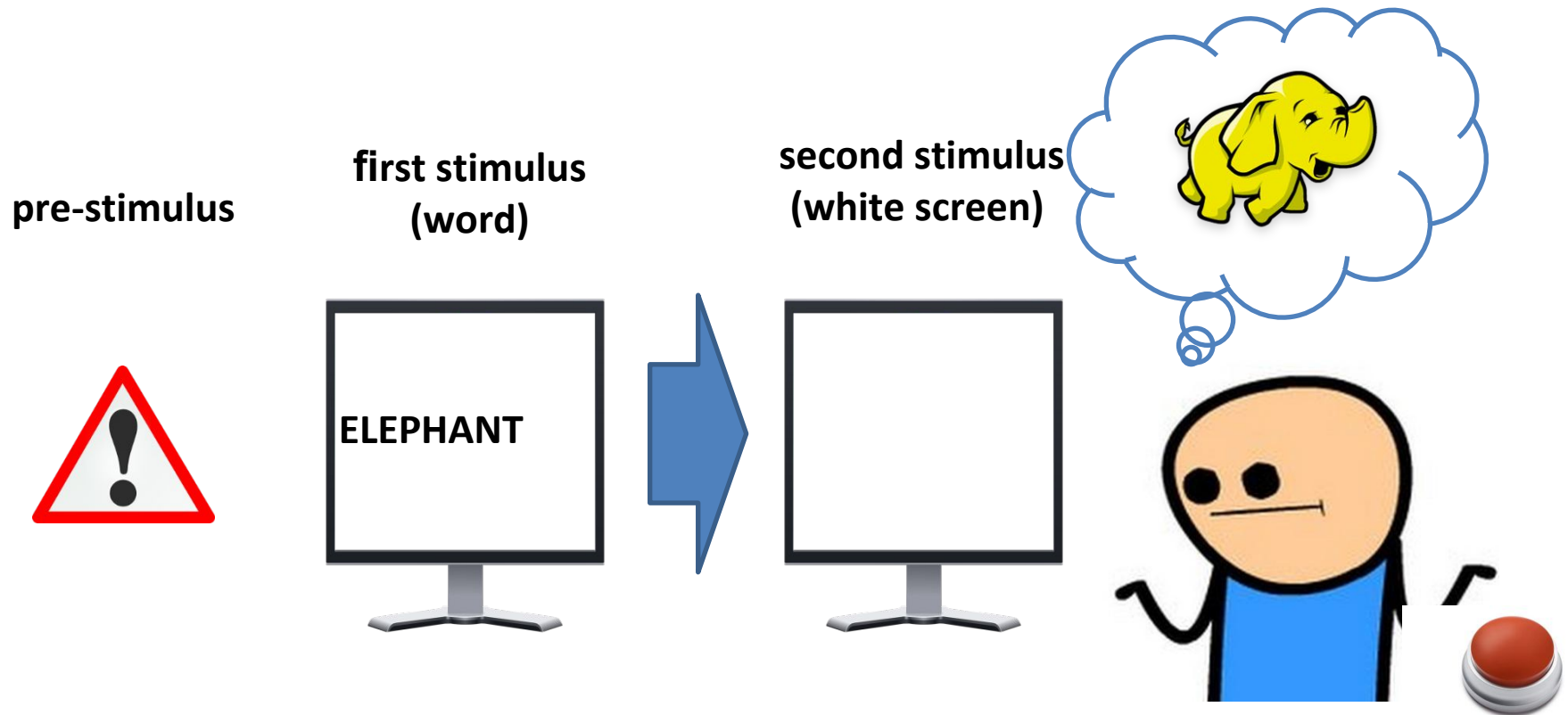
- Tasks SA and MA were presented in trials, each trial consists of 80 probes;
- The pre-stimulus interval is 300 ms, the duration of the first stimulus (word) is 400 ms, the duration of the second stimulus triggering the imagination or recall processes (white screen) is 5000 ms, the interval between the two stimuli in the sample is 800 ms.

Experiment: pre-training



memorizing color images and corresponding nouns

Mental attention (MA)



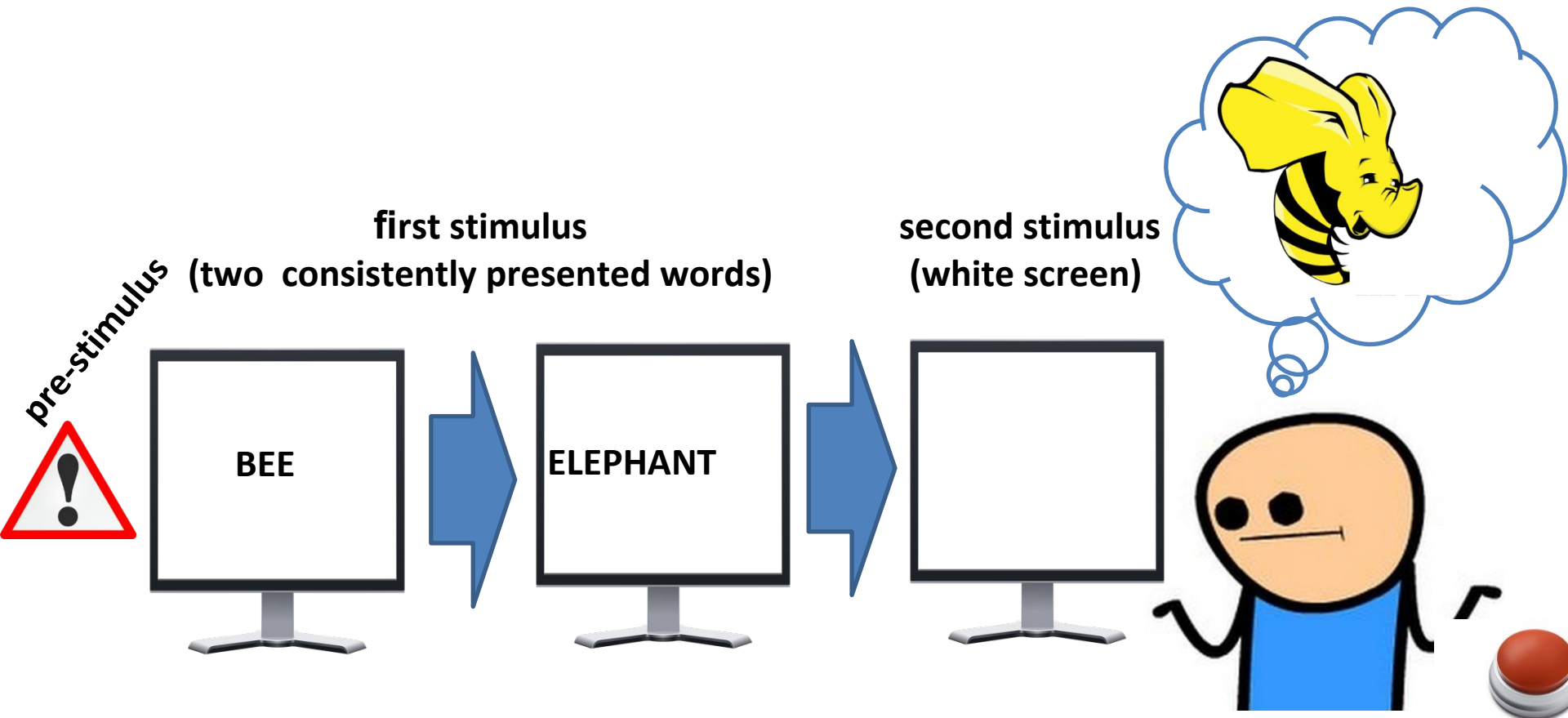
300 ms

400 ms

800 ms

5000 ms

Sensory attention (SA)



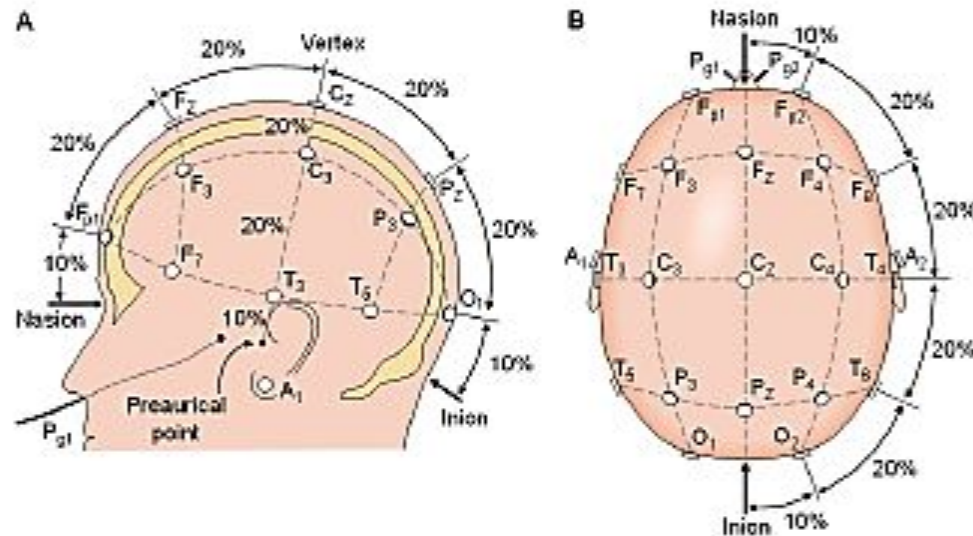
300 ms

400 ms

800 ms

5000 ms

Experiment details



- EEG registration by 19-channel electroencephalograph "Mizar -202" (<http://www.mitsar-medical.com>);
- Electroencephalographic cap Electro-Cap (www.electro-cap.com);
- 19 electrodes were located in accordance with the system 10-20 and reference electrodes on the ear lobes;
- Sampling frequency was 500 Hz;

Data processing

- High-pass (30Hz) and low-pass (0.53Hz) filters were performed;
- Band-rejection filter 45-55Hz;
- Artifacts were removed by Infomax-ICA (Independent Component Analysis);
- Polynomial detrending;
- The wavelet transformation was carried out in the range from 4 to 30 Hz;
- 171 combinations for 19 channel EEG is possible;

The wavelet transformation was done for

a grid of 20 frequencies (range: 4-30 Hz) for each electrode independently,

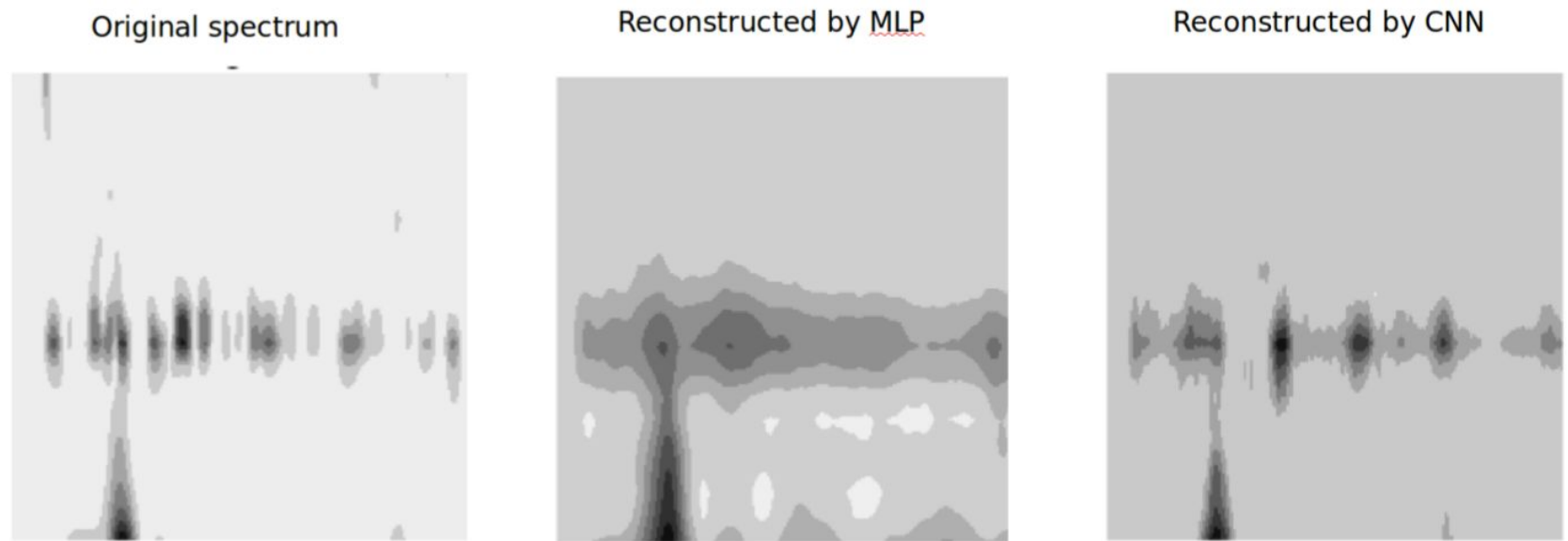
The minimum sample length in the experiment was 3480 counts or 6.96 seconds;

Each power spectrum were normalized to the average power value during the prestimulus interval.

The power spectrum for each channel was represented as

an grayscale image by the dimension of the number of frequencies per tim

Autoencoder training



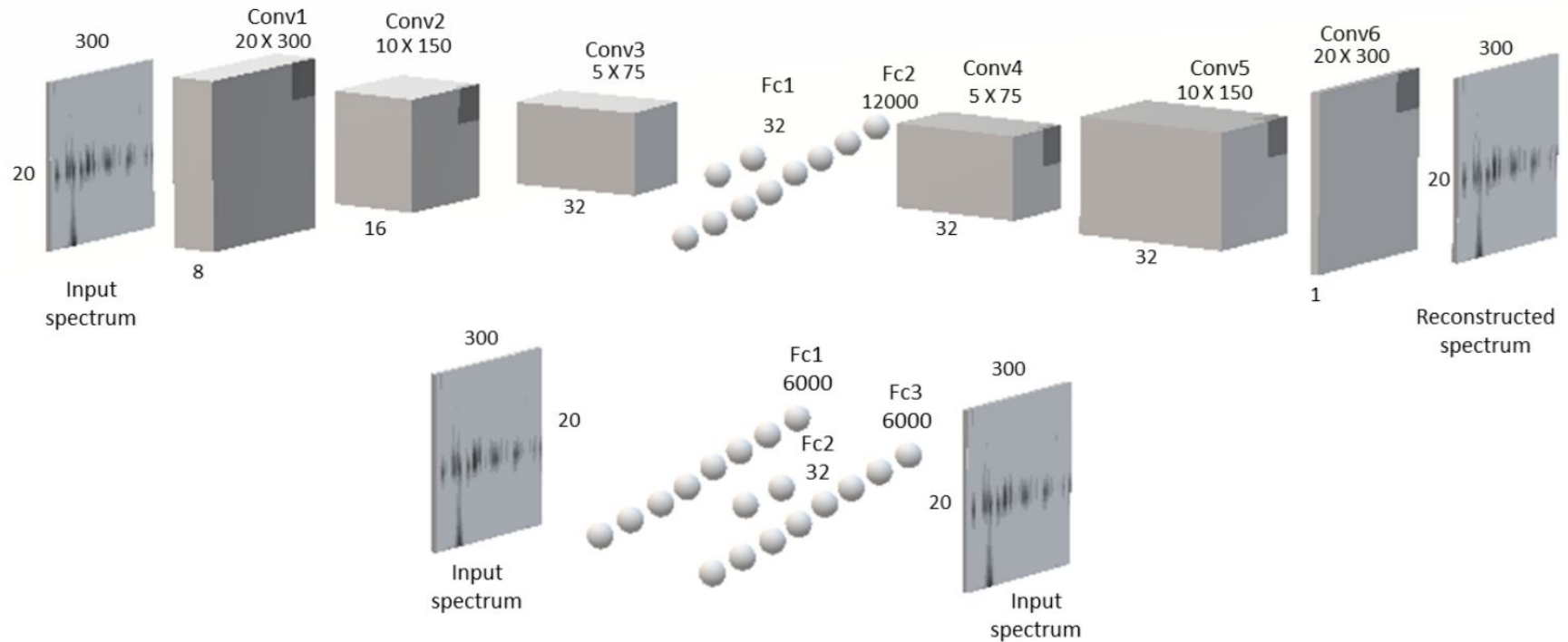
all EEG channels independently during training;

the amount of the training set was increased and consist of more than 100,000 samples;

Validation set consisted of 10% randomly selected samples with replacemen;

The training process was stopped if the error, calculated on the validation set, did not decrease during 500 epochs

Autoencoder models



Number of weights:

800 000 for CNN autoencoder

380 000 for dense autoencoder

Loss function: mean square error

Optimization algorithm: adamax.

Classification problem

Two approaches:

training universal classifier on data of whole group of subject

training own models for each person

Hint: to **exclude the the effect of random splitting** data to train (80%) and test (20%) sets computational experiments were returned 5 times

Classification model: shallow neural network with fully connected layers

Results

Classification errors and corresponding channel name

	Best chan1 (error)	Chan 2(error)	Chan 3 (error)
subj_7	1.2% (O2)	1.8% (T5)	2.4% (P3)
subj_19	7.9% (Pz)	9.3% (P4, O2)	15% (Pz)
subj_16	10% (Pz)	12.5% (T6)	13.8% (F4, C3, C4, P3, P4, O2)
mean_all_subj	16.6% (Fz)	17.9% (T5)	18.6%(T6, O1, O2)

Strongly depends on person:

The minimum error obtained value is 1.2%, but maximum value is 31.2%;

The best results are demonstrated on wavelet spectra of the electrodes O1, O2 and T6.

Conclusions and Future Work

- With the methods of phase wavelet coherence we have been obtained that the reproductive and productive imagination processes are quite similar from the point of view of psychophysiology;
- Fast GPU-based computation allows to use phase wavelet coherence method additionally the wide-spread spectral power based methods;
- It's possible to compute synchronization of different-scale events in addition to synchronization at the same frequencies.

Thank you for your attention!

This study has been performed at the expense of the grant of Russian Science Foundation (project no. 18-11-00336)